Three-dimensional valve repair—the better care? Midterm results of a saddle-shaped, rigid annuloplasty ring in patients with ischemic mitral regurgitation

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Objectives: Undersized ring annuloplasty is the treatment of choice for functional mitral regurgitation. However, recurrence of mitral regurgitation within the first years is frequent. The aim of this study was to analyze the functional and clinical outcome after mitral valve repair with the 3-dimensional saddle-shaped Edwards GeoForm (Edwards Lifesciences LLC, Irvine, Calif) annuloplasty ring in patients with ischemic mitral regurgitation.

Methods: Between November 2006 and November 2012, 70 patients (mean age, 68 ± 10 years; mean left ventricular ejection fraction, 40% ± 15%) with functional mitral regurgitation due to ischemic cardiomyopathy underwent mitral valve repair with the Edwards GeoForm annuloplasty ring. Concomitant procedures, such as coronary artery bypass grafting (75.7%), tricuspid valve repair (25.7%), aortic valve replacement (8.6%), and the Maze procedure (4.3%), were performed in 92.9% of patients. Follow-up is 97% complete (mean, 3.0 ± 1.7 years). Transthoracic echocardiography was obtained 2.4 ± 1.7 years postoperatively.

Results: Thirty-day mortality was 5.9%. Overall survival at 5 years was 71.3% ± 6.9%. At 4 years, overall freedom from recurrence of mitral regurgitation grade 3+ or greater was 92.5% ± 3.6%, and freedom from recurrence of mitral regurgitation grade 2+ or greater was 71.0% ± 8.7%. Three patients required a mitral valve–related reoperation for ring dehiscence. New York Heart Association functional class improved from 3.6 ± 0.6 to 1.6 ± 0.6 during follow-up ($P < .05$). Mean mitral valve pressure gradient was 3.3 ± 1.8 mm Hg across all ring sizes at the time of follow-up.

Conclusions: Mitral valve repair with the 3-dimensional saddle-shaped Edwards GeoForm annuloplasty ring in case of ischemic mitral regurgitation shows a low rate of recurrent regurgitation at 4 years. Clinically relevant mitral stenosis was not detected. The importance of secure anchoring of the device in the mitral annulus has to be emphasized to prevent ring dehiscence. (J Thorac Cardiovasc Surg 2014;148:176-82)

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Functional mitral regurgitation (FMR) as a consequence of regional or global left ventricular (LV) dysfunction despite a structurally normal mitral valve (MV) is a common complication in patients with ischemic heart disease or idiopathic dilated cardiomyopathy.[1] FMR is strongly associated with adverse outcome in patients with both ischemic and dilated cardiomyopathy.[2] The survival of patients with ischemic mitral regurgitation (IMR) was 30% after 5 years.[2] Moreover, its presence increases intermediate-term risk with a 2-year actuarial survival of 71% after surgical MV repair.[3] To date, the optimal strategy for the management of severe FMR is still controversial, and current guidelines recommend surgical treatment but do not indicate whether to repair or replace the MV.[4] In a recently published meta-analysis by Vassileva and colleagues,[5] MV repair for IMR is associated with better short- and long-term survival compared with MV replacement. On the other hand, Maltais and colleagues[6] showed in a single-center study that the surgical technique did not influence long-term survival in patients with ischemic cardiomyopathy.

In case of MV repair, undersized ring annuloplasty is currently used as the method of choice to treat FMR.[7] Although early results with this technique are satisfactory, late recurrence of FMR has been observed in a significant number of patients.[8,9] It is supposed that MV repair with an increased coaptation length is associated with more durable results, especially by application of an annuloplasty ring with a reduced anteroposterior (A-P) dimension.[10] To address this issue, the GeoForm annuloplasty ring (Edwards Lifesciences LLC, Irvine, Calif) was introduced to the market in 2005. The GeoForm

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Abbreviations and Acronyms
AF = atrial fibrillation
A-P = anteroposterior
FMR = functional mitral regurgitation
IMR = ischemic mitral regurgitation
LV = left ventricular
MV = mitral valve
NYHA = New York Heart Association

annuloplasty ring is characterized by its reduced A-P distance (41% reduction compared with Carpentier-Edwards Physio [Edwards Lifesciences LLC]). In addition to the marked reduction of the A-P diameter, the 3-dimensional elevation of the ring in the middle of the P2 segment (6-mm lift) raises the posterior MV annulus to counteract the downward pull of the enlarged left ventricle and compensates the restriction of the posterior leaflet.

The aim of the present study was to analyze the clinical and functional outcome after MV repair with the GeoForm annuloplasty ring in patients with IMR.

MATERIALS AND METHODS

Inclusion Criteria

Between November 2006 and November 2012, 70 patients with FMR due to ischemic cardiomyopathy underwent MV repair with the Edwards GeoForm annuloplasty ring at the German Heart Center Munich. A diagnosis of FMR was made in patients in whom MR was present with regional wall motion abnormalities with normal valve leaflets and intact papillary muscles (Carpentier Class IIIb). All patients with other types of MR (ie, FMR due to dilated cardiomyopathy or degenerative MV disease) or patients with endocarditis were excluded. Clinical symptoms, hemodynamic data, and functional outcome were obtained from medical records, patients' follow-up visits, mailed questionnaires, telephone interviews with the patient or family members, and communications from the referring physicians.

Echocardiography

Echocardiographic examinations were performed with a Siemens Sequoia Acuson System (Munich, Germany) using a 2.5-MHz imaging transducer and included M-mode, continuous-wave 2-dimensional, pulsed-wave Doppler, and color Doppler analyses. The severity of regurgitation was classified as none/trivial (0+), mild (1+), moderate (2+), moderate-severe (3+), or severe (4+) and assessed in a semi-quantitative manner by means of color Doppler flow mapping. For detection of regurgitation, a color flow Doppler was used with a Nyquist limit (aliasing velocity of 50–60 cm/sec) and a color gain that just eliminated random color speckle from nonmoving areas. The vena contracta was measured in the parasternal long-axis view as the narrowest portion of the jet that occurred at the orifice. The color flow sector was as narrow as possible with the least depth to maximize lateral and temporal resolution. All evaluations were carried out according to standard techniques recommended by the American Society of Echocardiography.[11]

Operative Technique

All operations were performed on cardiopulmonary bypass under moderate systemic hypothermia (30°C-32°C). Myocardial protection was achieved using cold (4°C) antegrade crystalloid (Custodiol, Koehler Chemie; Alsbach-Haehnlein, Germany) or antegrade blood cardioplegia, and the MV was exposed through a left atrial or a trans-septal approach, depending on the preference of the surgeon.

Sizing was primarily based on the length of the anterior mitral leaflet. Because of the significantly reduced A-P distance of the Edwards GeoForm ring, downsizing is not necessary and was never performed. Thus, ring size was chosen so that the provided sizer totally covered the anterior leaflet for sufficient coaptation. In addition, the intertrigonal distance serves as an additive tool to find an optimal correlation between the height and the width of the anterior leaflet.

All patients were discharged with a regimen of phenprocoumon (Marcumar; MEDA Pharma, Bad Homburg, Germany) for the first 3 months postoperatively. After 3 months, anticoagulant therapy was continued only in patients with permanent atrial fibrillation (AF) or severely depressed LV function.

Follow-up

Complete follow-up was achieved in 97.1% of patients (68/70), yielding a cumulative total of 173 patient-years. The follow-up was closed on January 31, 2013. As of January 2013, 55 patients are alive (mean, 3.0 ± 1.7 years). Postoperative complications were analyzed according to the "Guidelines for Reporting Morbidity and Mortality after Cardiac Valvular Operations" approved by the Society of Thoracic Surgeons. The study protocol was approved by the local governmental ethics committee (approval reference number: 5247/11).

Statistical Analysis

Statistical analysis was performed with IBM SPSS Statistics 21 (SPSS Inc, Chicago, Ill). Continuous variables are reported as mean ± standard deviation or median (range) for skewed data. Categoric variables are reported as absolute and relative frequencies. To test for changes in New York Heart Association (NYHA) classification and MR grade, the sign test was used. The Kaplan–Meier method was used to estimate overall survival. Survival estimates are reported as the mean ± standard deviation. All reported *P* values are 2 sided and have not been adjusted for multiple testing.

RESULTS

Preoperative Variables

The mean age at operation was 68 ± 10 years (range, 42-88 years), and 46 of 70 patients (65.7%) were male. Preoperative clinical and hemodynamic data are summarized in Table 1. Preoperative echocardiographic assessment was performed in every patient by the referring cardiologist and repeated after patients' admission, usually 1 or 2 days before surgery. Eight patients (11.4%) showed MR 4+ (vena contracta ≥7 mm), 55 patients (78.6%) showed MR 3+ (vena contracta ≥5 mm and <7 mm), and 7 patients showed MR 2+ (vena contracta ≥3 mm and <5 mm). Thirty-seven patients (52.9%) had a history of preoperative myocardial infarction at an average of 5.5 ± 8.0 years before the operation. The preoperative NYHA functional class was assessed at the time of admission; 5 patients (7.1%) presented with NYHA class II, 21 patients (30.0%) presented with NYHA class III, and 44 patients (62.9%) presented with NYHA class IV. Five patients (7.1%) had previous cardiac surgery other than on the MV.

All patients were preoperatively treated with medication for congestive heart failure. Medication at the time of

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TABLE 1. Preoperative data

No. of patients (n)	70
Male/female (n)	46/24
Age (y)	68 ± 10
NYHA class (n, %)	
II	5 (7.1)
III	21 (30.0)
IV	44 (62.9)
Preoperative rhythm (n, %)	
Sinus rhythm	51 (72.9)
AF 12 (17.1)	
Paced rhythm	7 (10.0)
LV ejection fraction (%)	40 ± 15
Preoperative MV regurgitation (grade)	3.0 ± 0.4
Previous myocardial infarction (n, %)	37 (52.9)
Previous cardiac operation (n, %)	5 (7.1)

Data shown are mean ± SD. *AF,* Atrial fibrillation; *LV,* left ventricular; *MV,* mitral valve; *NYHA,* New York Heart Association.

TABLE 2. Operative data

Operative mortality (n, %)	4 (5.9%)
Ring size (labeled) (n, %)	
26	4 (5.7)
28	22 (31.4)
30	24 (34.3)
32	20 (28.6)
Concomitant procedures (n, %)	
None	5 (7.1)
CABG	53 (75.7)
Tricuspid valve repair	18 (25.7)
Aortic valve surgery	6 (8.6)
AF ablation	3 (4.3)
Aortic crossclamp time (min)	96 ± 28
Bypass time (min)	145 ± 42
Intra-aortic balloon pump (n, %)	16 (22.9)
MV repair techniques (n, %)	
Isolated ring annuloplasty	55 (78.6)
Chordal replacement anterior mitral leaflet with PTFE sutures	7 (10.0)
Wooler-type suture	1 (1.4)
Chordal cutting	1 (1.4)
Pseudo-commissure closure	4 (5.7)
Combined techniques	2 (2.9%)

Data shown are mean ± SD. *AF*, Atrial fibrillation; *CABG,* coronary artery bypass grafting; *MV,* mitral valve; *PTFE*, polytetrafluoroethylene.

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admission was as follows: Some 36% of patients were treated with diuretics, angiotensin-converting enzyme inhibitors, and beta-blockers, as recommended by the European Society of Cardiology Guidelines for the diagnosis and treatment of acute and chronic heart failure 2012.[12] Some 33% of patients were treated with diuretics and beta-blockers, 8% of patients were treated with angiotensin-converting enzyme inhibitors and beta-blockers, 10% of patients were treated with angiotensin-converting enzyme inhibitors and diuretics, and 13% of patients were treated with only diuretics, angiotensin-converting enzyme inhibitors, or beta-blockers.

Operative Data

Thirty-day mortality was 5.9% (n = 4), attributed to low cardiac output (n = 2) and septic multiorgan failure (n = 2). A total of 5 patients (7.1%) underwent isolated MV repair, and 65 patients (92.9%) underwent MV repair with a concomitant cardiac procedure: coronary artery bypass grafting (n = 53), tricuspid valve surgery (n = 18), and aortic valve surgery (n = 6). Nine patients underwent MV repair in combination with coronary artery bypass grafting and tricuspid or aortic valve surgery. The average ring size was 29.7 ± 1.8 mm. Table 2 shows the distribution of the ring sizes for the entire cohort. The mean cardiopulmonary bypass time was 145 ± 42 minutes, and the mean aortic crossclamp time was 96 ± 28 minutes. Fifty-five patients (78.6%) had an isolated ring implantation. If residual MR was detected by water test during surgery, additional repair techniques were applied in 15 patients (21.4%). Operative data are summarized in Table 2.

Follow-up Data

All 70 patients had an echocardiographic assessment at hospital discharge (65 patients) or during the hospital stay (in case of hospital death, 5 patients) at a mean time of 7.8 ± 3.7 days postoperatively. At this early echocardiographic examination, MR was none/trivial (0+/4+) in 36 patients (51.4%), mild (1+/4+) in 29 patients (41.4%), moderate (2+/4+) in 4 patients (5.7%), and severe (4+/4+) in 1 patient (1.4%) who had immediate reoperation. Two patients (2/70) were lost to follow-up (completeness of follow-up 97.1%).

In total, 63 of 70 patients (5 in-hospital deaths, 2 patients lost to follow-up) had an echocardiographic assessment at a mean of 2.4 ± 1.7 years postoperatively (range, 3 months to 5.6 years, except the patient with severe MR, who underwent reoperation at postoperative day 11). Echocardiographic follow-up is 100% complete.

Figure 1 shows a comparison of MR preoperatively, at hospital discharge or during hospital stay (postoperatively), and at latest follow-up of 63 of 70 patients (5 in-hospital deaths, 2 patients lost), including echocardiography results of 3 patients before reoperation.

At the latest echocardiographic examination, MR was none/trivial (0+/4+) in 25 patients (39.7%), mild (1+/4+) in 25 patients (39.7%), moderate (2+/4+) in 9 patients (14.3%), moderate-severe (4+/4+) in 1 patient (1,6%), and severe (4+/4+) in 3 patients (4.8%) who had reoperation. In these 3 patients, MV-related reoperation was required 11 days, 6 months, and 7 months after the initial operation. The indication for reoperation was recurrent MR caused by ring dehiscence in the region of the posterior ring (P2). At 4 years, Kaplan–Meier analysis revealed 92.5% ± 3.6% freedom from recurrence of MR

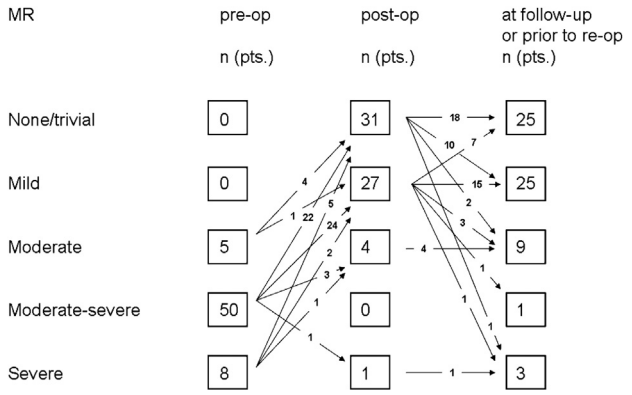

FIGURE 1. Comparison of MR preoperatively, at hospital discharge or during hospital stay (postoperatively), and at latest follow-up. Data of 63 of 70 patients (5 in-hospital deaths, 2 patients lost to follow-up), including echocardiography results of 3 patients before reoperation. *MR,* Mitral regurgitation.

grade 3+ to 4+ (ie, moderate-severe and severe) (Figure 2) and 71.0% ± 8.7% freedom from recurrence of MR grade 2+ (ie, moderate).

Mean MV pressure gradients were 3.3 ± 1.8 mm Hg across all ring sizes at the time of follow-up. NYHA functional class improved from 3.6 ± 0.6 to 1.6 ± 0.6 during follow-up ($P < .05$). LV ejection fraction assessed by echocardiography increased from 40% ± 15% (before surgery) to 50% ± 9% at latest follow-up. The difference did not reach significance.

All patients were postoperatively treated with medication for congestive heart failure. Medication at the time of follow-up was as follows: Some 68% of patients were treated with diuretics, angiotensin-converting enzyme inhibitors, and beta-blockers as recommended by the European Society of Cardiology Guidelines for the diagnosis and treatment of acute and chronic heart failure 2012.[12] Some 18% of patients were treated with diuretics and beta-blockers, 6% of patients were treated with angiotensin-converting enzyme inhibitors and beta-blockers, 4% of patients were treated with angiotensin-converting enzyme inhibitors and diuretics, and 4% of patients were treated only with angiotensin-converting enzyme inhibitors.

Eleven patients died late after a median time of 1.6 ± 1.3 years (31 days to 3.6 years) after the operation. The cause of death could be assessed in only 3 of 11 patients. Two patients died of cardiac-related causes, and 1 patient died of septic multiorgan failure. Overall survival at 5 years was 71.3% ± 6.9% (Figure 3).

DISCUSSION

The present study reports for the first time the midterm results of a series of patients who underwent MV repair with the new 3-dimensional Edwards GeoForm annuloplasty ring in patients with IMR.

The main finding of this study is that freedom from recurrence of MR grade 3+ to 4+ (ie, moderate-severe and severe) was 92.5% ± 3.6% at 4 years, and freedom from recurrence of MR grade 2+ (ie, moderate) was 71.0% ± 8.7% at 4 years.

The 3-dimensional GeoForm annuloplasty ring, first introduced by Edwards in 2005, is a complete rigid ring

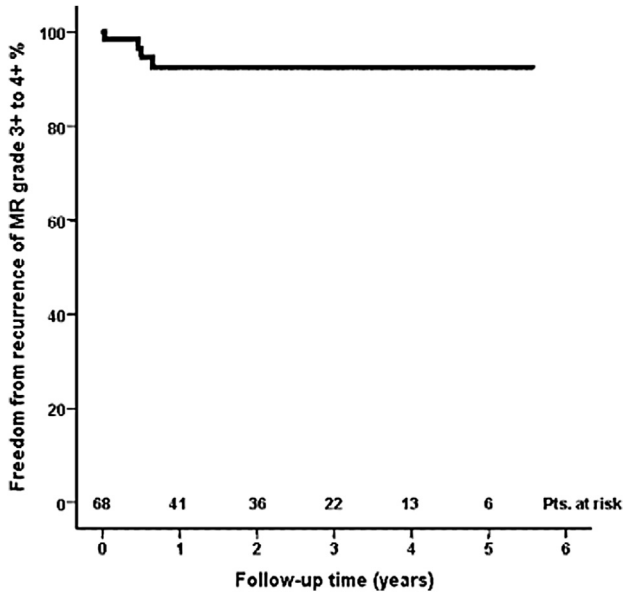

FIGURE 2. Kaplan–Meier estimate of freedom from recurrence of MR grade 3+ to 4+ (ie, moderate-severe and severe) of 68 patients with IMR who underwent MV repair with the Edwards GeoForm annuloplasty ring (Edwards Lifesciences LLC, Irvine, Calif). *MR,* Mitral regurgitation.

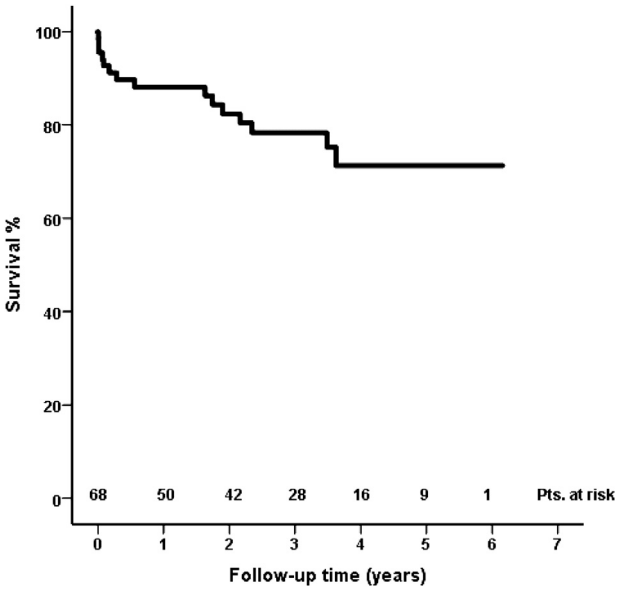

FIGURE 3. Kaplan–Meier estimate of survival function for 68 patients with IMR who underwent MV repair with the Edwards GeoForm annuloplasty ring.

and has a silicone-wrapped titanium core with velour cloth. It is characterized by its reduced A-P distance (41% reduction compared with the Carpentier-Edwards Physio), which brings the annulus inward to counteract the outward pull of the left ventricle. In addition, the elevation of the ring at the P2 segment (6-mm lift) raises the MV apparatus to counteract the downward pull of the enlarged left ventricle. In a computational model of the MV, Maisano and colleagues[13] demonstrated that an annular prosthesis with selective reduction in the A-P dimension is theoretically more effective than a nonprofile ring for treating leaflet tethering in FMR. However, recent studies in the normal beating ovine heart suggested that 3-dimensional rigid complete annuloplasty rings increase anterior mitral leaflet strain, which may affect repair durability.[14] To address these issues, we analyzed the midterm results of a large series of patients with FMR due to ischemic cardiomyopathy who underwent MV repair with the Edwards GeoForm annuloplasty ring.

Patients with ischemic or dilated cardiomyopathy often develop FMR as a consequence of regional or global LV dysfunction despite a structurally normal MV.[1] IMR as a consequence of myocardial infarction is caused by leaflet tethering and restriction of motion, whereas dilative MR is caused by annular enlargement and central malcoaptation.[15] The presence of FMR has a poor prognosis with a clear relationship between MR severity and reduced survival.[16] Survival in patients with severe FMR and medical management at 5 years is approximately 30%.[2,16,17] Even with coronary artery bypass grafting alone, IMR is not corrected in most cases and leaves many patients with significant residual MR, as shown by Aklog and colleagues[18] in a series of 136 patients.[18] Therefore, guidelines of societies recommend surgical treatment for patients with symptomatic severe FMR, but they do not indicate whether to repair or replace the MV.[4]

On decision-making in case of FMR, the surgeon has to balance between a lower operative morbidity and mortality in case of MV repair and a better long-term correction of MR in case of valve replacement. In a recent published meta-analysis by Vassileva and colleagues,[5] MVR for IMR is associated with better short- and long-term survival compared with MV replacement. On the other hand, Murphy and colleagues[19] stated in a review article that there is no convincing evidence that repair is superior to replacement in case of surgery for IMR.

The operative mortality of 5.9% in our study population is comparable to other reported rates ranging from 3.8% to 12%.[20-22] In 2011, De Bonis and co-workers[23] first published retrospective data concerning the Edwards GeoForm annuloplasty ring in 74 patients with ischemic or dilated cardiomyopathy. The hospital mortality was 9.4%, and the overall survival was 81.1% ± 6.6% at 3.5 years.[23] This is also comparable to our data, in which Kaplan–Meier analysis revealed 71.3% ± 6.9% overall survival at 5 years after MV repair with the Edwards GeoForm annuloplasty ring.

Another study published by De Bonis and colleagues[24] reported an overall survival of 73.0% ± 10.9% at 3.7 years in 79 patients undergoing MV repair in ischemic or dilated cardiomyopathy. A complete rigid or semirigid undersized ring annuloplasty (with or without edge-to-edge technique) was used in their study.[24] In a retrospective study performed on 257 consecutive patients, Crabtree and colleagues[21] reported a 68.3% actuarial 3-year survival, which is similar to our results, especially examining patients with IMR.

In a retrospective nonrandomized trial, McGee and colleagues[8] reported on a high-grade MR in 28% of patients 6 months after MV annuloplasty for functional IMR. These results were confirmed in the study by Crabtree and colleagues,[21] in which 28% of patients presented with 3+ to 4+ MR 20 ± 25 months after MV repair for IMR. In both studies, mainly flexible rings or bands had been used.[8,21] Therefore, alternative approaches have been attempted, for example, papillary muscle relocation.[25] In contrast, the combination of the edge-to-edge technique with an undersized ring annuloplasty can significantly improve the durability of the repair in patients with end-stage dilated cardiomyopathy.[20,24] Recurrent severe mitral regurgitation was present in 3.7% of patients with undersized ring annuloplasty and additional edge-to-edge technique compared with 21.7% of patients with undersized ring annuloplasty only.[20,24]

In our study, cohort freedom from recurrence of MR grade 3+ to 4+ (ie, moderate-severe and severe) was 92.5% ± 3.6% at 4 years and freedom from recurrence of MR grade 2+ (ie, moderate) was 71.0% ± 8.7% at 4 years. These data are comparable to those of De Bonis and colleagues.[23] At 3.5 years, they demonstrated an overall freedom from MR 3+ or greater of 85.1% ± 8% and an overall freedom from MR 2+ or greater of 75.1% ± 8.6% in their retrospective data concerning the Edwards GeoForm annuloplasty ring in patients with ischemic or dilated cardiomyopathy.[23] Taken together, our data and the data of De Bonis and colleagues[23] show a lower percentage of patients presenting with MR 3+ or greater or MR 2 or greater at 4 or 3.5 years postoperatively than studies in which flexible rings or bands had been used.[8,21] During follow-up, there were 1.9 ± 0.9 echocardiographic assessments per patient without taking into account the echocardiographic assessment before hospital discharge (postoperatively).

When comparing MR postoperatively and at latest follow-up, there are only a few patients in whom MR worsened over time. Four of the 9 patients with moderate MR at follow-up already had moderate (2+/4+) MR at hospital discharge, which remained stable over time.

Moderate to severe MR developed in 1 patient 3 years postoperatively, but the patient refused reoperation.

Severe MR developed postoperatively in 3 patients of our cohort. They required an MV-related reoperation 11 days, 6 months, and 7 months after the initial operation. The indication for reoperation was recurrent MR caused by posterior dehiscence of the GeoForm annuloplasty ring, which was documented intraoperatively. The stress forces on the posterior part of the ring (elevated P2 segment, 6 mm lift) caused by the downward pull of the enlarged LV were responsible for the dehiscence. All of these events occurred in the beginning of our experience with the GeoForm annuloplasty ring. Thus, we now place additional Teflon felt–reinforced sutures in the posterior part of the ring. We emphasize the importance of exact placement of the annuloplasty sutures deep and precisely into the mitral annulus and the additional use of Teflon felt–reinforced sutures in the posterior part of the ring (6-mm lift) to ensure secure fixation.

Clinically relevant mitral stenosis was not detected, whereas mean pressure gradients across the MV were 3.3 $\pm$ 1.8 mm Hg across all ring sizes at the time of follow-up. This was also confirmed by De Bonis and colleagues[23] in patients at rest and in a small number of patients during exercise echocardiography.

Moreover, a significant clinical improvement was documented in our patients, reflected by a significant improvement in NYHA functional class. This was due to not only our ring annuloplasty but also myocardial revascularization and a postoperatively extended therapy for congestive heart failure.

Study Limitations

This study was performed in a retrospective manner. Effects of the 3-dimensional annuloplasty ring on the left ventricle after MV repair for ischemic MR were not studied. On the other hand, in case of LV remodeling, it is difficult to differentiate what causes the effects: the 3-dimensional annuloplasty ring itself, the repaired MV, the concomitant procedures, or the congestive heart failure therapy. Magnetic resonance imaging would be a suitable tool to work out such issues, but most of these patients are not suitable because of exclusion criteria (eg, previous pacemaker or defibrillator implantation, AF, poor general condition). The Maze procedure was performed in only 3 of 12 patients presenting with AF. The rationale for this low rate of AF ablation was to avoid longer crossclamp times in this sick patient population. We have now changed our policy concerning this issue and try to treat all patients with AF regardless of a patient's principal diagnosis.

CONCLUSIONS

MV annuloplasty with the Edwards GeoForm ring in case of ischemic cardiomyopathy shows low rates of recurrent mitral regurgitation in the midterm and may lead to an improvement of clinical and functional status of the patients. The importance of secure anchoring of the device in the mitral annulus has to be emphasized to prevent ring dehiscence. Surgical intervention remains the mainstay of therapy in these patients because the results with medical management have not been favorable. In case of IMR, we prefer 3-dimensional valve repair.

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